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Computational Analysis of Heat Transfer through Fins with Different Types of Notches

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***Abstract*—*The Engine is one of the important component in an automobile which is subjected to high temperature and thermal stresses. In order to cool the engine the fins are another component which are used to dissipate the heat from the Engine. Fins are generally used to increase the heat transfer rate from the system to the surroundings. By doing computational flow analysis on the engine cooling fins, it is helpful to know about the heat dissipation rate and the Principle implemented in this project is to increase the heat transfer rate, so in this analysis, the fins are modified by putting different types of notches and are of same material. The knowledge of efficiency and effectiveness of the fins are necessary for proper designing of fins. The main objective of our analysis is to determine the flow of heat at various notches available and the analysis is done by using ANSYS – CFD Fluent software.*

***Keywords*— CFD, Flow over fins, Notches, Cooling system and analysis.**

I. INTRODUCTION

Heat transfer is a thermal energy which occurs in transits due to temperature difference. Cooling system is one of the important system among all of the systems in automobile. Fins are responsible to carry out the produced heat inside the cylinder , for the heat transfer there are various modes like conduction , convection and radiation are taken place. From these modes conduction is carried out in engine cooling fins. There are two different types of cooling system that are used in the automobiles, they are:

1. Air Cooling
2. Water cooling

1. Air-Cooling : Mostly automobile bikes using direct air cooling (without an intermediate liquid) were built over a long period beginning with the advent of mass produced passenger cars and ending with a small and generally unrecognized technical change.

2. Liquid Cooling: Liquid cooling is also employed in maritime vehicles. For vessels, the seawater itself is mostly used for cooling. In some cases, chemical coolants are also employed (in closed systems) or they are mixed with seawater cooling. By doing the computational Fluid analysis the heat transfer rate of the fins with various types of notches are analyses by using ANSYS-14.5 .

II. LITERATURE REVIEW

"Deepak Gupta, Wankhade S.R.", Design and Analysis of Cooling Fins in this paper the author tells about Cooling fins are used to increase the heat transfer rate of specified surface. Engine life and effectiveness can be improved with effective cooling. The main aim of the project is to study and comparing with100 cc Hero Honda Motorcycle fins and analyze the thermal properties by varying geometry, material and thickness. The analysis is done using ANSYS[1]. "Sanjay Kumar Sharma and Vikas Sharma" , Maximizing The Heat Transfer through Fins using CFD as a Tool in this author describes This study presents the results of computational numerical analysis of air flow and heat transfer in a light weight automobile engine, considering three different morphology pin fins. The results indicate that the drop shaped pin fins show improved results on the basis of heat transfer and pressure drop by comparing other fins [2]. "S.Jamala Reddy, Y.Tejeswar " , Design and Thermal Analysis of Cooling Fins by Varying its Geometry and Material in this paper The main purpose of using these cooling fins is to cool the engine cylinder by air. The main aim of the project is to analyze the thermal properties by varying geometry, material and thickness of cylinder fins. Transient thermal analysis determines temperatures and other thermal quantities that vary over time [3]. "Vivek Kumar, Dr. V. N. Bartaria", CFD Analysis of an Elliptical Pin Fin Heat Sink using Ansys Fluent v12.1 in the present study carries out numerical physical insight into the flow and heat transfer characteristics. The governing equations are solved by adopting a control volume-based finite-difference method with a power-law scheme on an orthogonal non-uniform staggered grid [4]. "G. Babu, M. Lavakumar" , Heat Transfer Analysis and Optimization of Engine Cylinder Fins of Varying Geometry and Material in this paper the main aim of the project is to analyze the thermal properties by varying geometry, material and thickness of cylinder fins. Parametric models of cylinder with fins have been developed to predict the transient thermal behavior. The models are created by varying the geometry, rectangular, circular and curved shaped fins and

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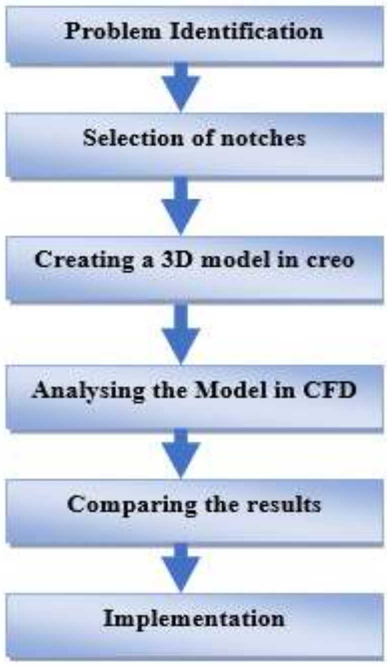
also by varying thickness of the fins [5]. “K. Sathishkumar and N. Ugesh” , Finite Element Analysis of a Shaft Subjected To a Load the author tells about the objective is to build a model and assemble the part files and to analyze the various stress and deformation. The part files and assembly are done by using CREO software and the analyzing are done by using a ANSYS software. The static analysis is used to analyze the stress and deformation of the shaft when it is subjected to a particular load and the modal analyze is executed to govern the vibration features (mode shapes and natural frequencies) of shaft [6]. “Sandhya Mirapalli, Kishore.P.S” , Heat Transfer Analysis on a Triangular Fin in this In an air-cooled engine, rectangular and triangular fins are provided on the periphery of engine cylinder. Heat transfer analysis is carried out by placing rectangular and then triangular fins. Analysis is carried out by varying temperatures on the surface of the cylinder from 200 ºC to 600ºC and varying length from 6 cm to 14 cm [7]. “K. Sathish Kumar” , Design and Analysis of I.C. Engine Piston and Piston-Ring on Composite Material using Creo and Ansys Software the author had analyzed the stress distribution is evaluated on the four stroke engine piston by using FEA. The finite element analysis is performed by using FEA software. The couple field analysis is carried out to calculate stresses and deflection due to thermal loads and gas pressure. These stresses will be calculated for two different materials. The results are compared for all the two materials and the best one is proposed. The materials used in this project are aluminium alloy, and SiC reinforced ZrB2 composite material [8]. “Mohsin A. Ali and Prof. (Dr.) S.M Kherde” , Design Modification and Analysis of Two Wheeler Engine Cooling Fins by CFD in this paper we understand about the main of aim of this work is to study different shapes and geometry of fins to improve heat transfer rate by changing fin geometry under different velocities [9]. “G. Lorenzini a, C. Biserni , R.L. Correa , E.D. dos Santos , L.A. Isoldi , L.A.O. Rocha” , Constructal design of T-shaped assemblies of fins cooling a cylindrical solid body in this work This paper considers the numerical optimization of a T-shaped assembly of fins cooling a cylindrical solid body. The objective is to minimize the maximum excess of temperature between the solid cylindrical body and the ambient. Internal heat generation is distributed uniformly throughout the solid body. The assemblies of fins are bathed by a steady stream with constant ambient temperature and convective heat transfer [10]. “K. Alawadhi, Abdulwahab J. Alsultan, S. Joshi, M. Sebzali, Esam. AM.Husain”, Computational Fluid Dynamics (CFD) Analysis of Natural Convection of Convergent-Divergent Fins in Marine Environments the author had tells about the validation of results of modeling and simulation in CFD. The simulation was carried out using the ANSYS 12.0 as the CFD modeling software. The main objective of the CFD analysis was to calculate the temperature distribution on the surface of the base plate and surface of the convergent-divergent fins for the given inline and staggered arrangement of fins due to the effect of natural convection heat transfer for different heat power inputs, and also to compare the CFD results with the experimental results [11]. “Pulkit Agarwal, Mayur Shrikhande and P. Srinivasan” , Heat Transfer Simulation by CFD from Fins of an Air Cooled Motorcycle Engine under Varying Climatic Conditions in this paper we understand that the heat transfer rate depends upon the velocity of the vehicle, fin geometry and the ambient temperature. Many experimental methods are available in literature to analyze the effect of these factors on the heat transfer rate. However, an attempt is made to simulate the heat transfer using CFD analysis [12]. “S.R.Durai Raju, Durai Balaji.M, Jaya Prakash.N, Jeevanandan.I.G” , Review On Engine Cooling System the author tells about the various work done by number of researchers for the enhancement of automobile cooling system is studied. An overview is given in this paper where engines efficiency is increased by analysing various cooling systems. The method of various cooling parameters are also explained with their quantity and results [13].

III. METHODOLOGY

In this paper we followed the methodology given in the flow chart below , first collect all the related information about the heat transfer and the cooling fins and then collecting some of the literature review.



After collecting all the related data’s the cooling fins are designed using CREO 2.0. After the model is created the analysis are done by using ANSYS – 14.5 (CFD – Fluent)

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. Then the results of each analysis are compared and then the best notch is selected. The result from the ansys is compared with the theoretical calculation.

IV. GEOMENTRIC MODELING AND MATERIAL PROPERTY

The Cooling fins are designed using CREO 2.0 in this design the 100 CC automobile Engine is selected for designing of cooling fins and the material is assumed as aluminium for analysis. The three different types of notches which are selected for analysis are,

1. Fins with Holes.
2. Fins with Rectangular Notches.
3. Fins with V – Shaped Notches.

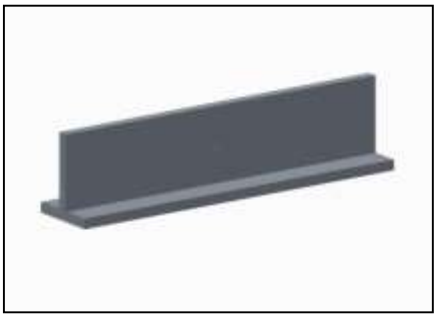

Fig: 1 Fins without any Notch

Fig: 2 Fins With Holes

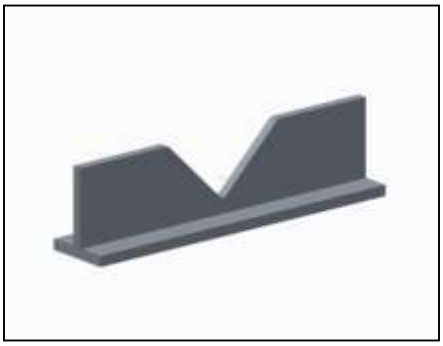

Fig: 3 Fins with V – Shaped Notch

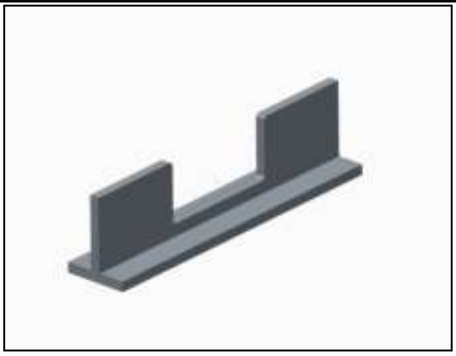

Fig: 4 Fins with Rectangle Notch

MATERIAL DATA FOR ALUMINIUM

For the analysis of cooling fins we had choose the material as aluminium because Aluminium is a good thermal and electrical conductor, having 59% the conductivity of copper, both thermal and electrical, while having only 30% of copper's density. Aluminium is capable of being a superconductor, with a superconducting critical temperature of 1.2Kelvin. The weight of the aluminium is less and also because of a high thermal conductivity, since aluminium is selected as the material for cooling fins.

Table.1: Material Data of the Aluminium

MATERIAL PROPERTY	*VALUE*
Density	2719 kg / m^3
Thermal Conductivity	202.399 W/m-k
Specific Heat	871 J/kg-k
Young's Modulus	3.4e+011 Pa
Poisson's Ratio	0.22
Bulk Modulus	2.0238e+011 Pa
Shear Modulus	1.3934e+011 Pa

V. CFD ANALYSIS AND MESH GENERATION

Computational Fluid Dynamics (CFD) is the science of determining numerical solution of governing equation for the fluid flow through space or time to obtain a numerical description of the complete flow field of interest. The equation can represent steady or unsteady, Compressible or Incompressible, and in viscid or viscous flows, including non ideal and reacting fluid behavior. The particular form chosen depends on intended application. The state of the art is characterized by the complexity of the geometry, the flow physics, and the computing time required obtaining a solution. After the model is imported in CFD domain, next step is to mesh the domain. To perform better results using CFD Tool it was mandatory to use better quality of mesh hence the meshing of the model is generated and the naming of the section is given in the model for computing purpose.

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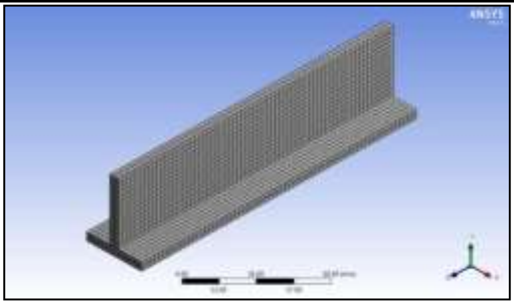

Fig : 5 Meshing model of a normal Fins

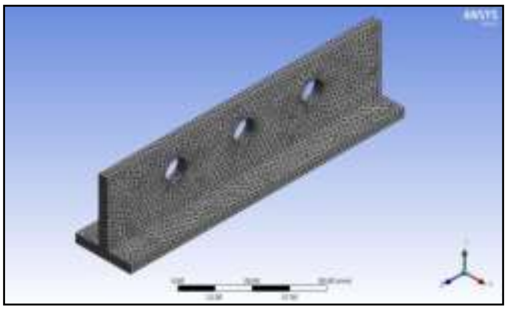

Fig : 6 Meshing model of a Fins with Holes

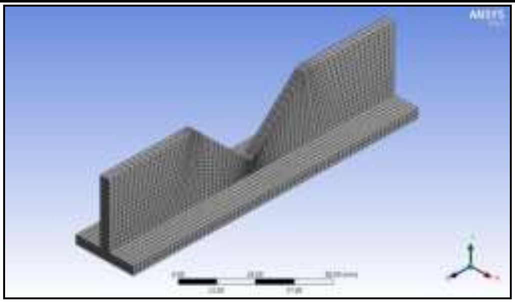

Fig : 7 Meshing model of a Fins with V –Shaped Notches

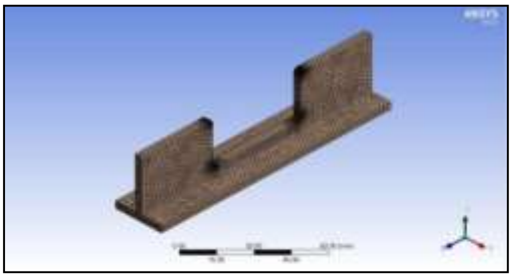

Fig : 8 Meshing model of a Fins with Rectangular Notches

In CFD mesh quality denotes the accuracy of the results and the quality of meshing will vary from each geometry and the meshing quality are tabulated below,

Table.2: Meshing Detail of the Model in CFD- Fluent

Fins Type	Cells	Faces	Nodes	Minimum Orthogonal Quality	Maximum Aspect Ratio
Normal Fins	3770	13383	5940	9.99404e-01	1.8562e+00
Fins with Holes	30440	65286	7395	2.49340e-01	1.7743e+01
Fins with V Shaped Notch	4408	15638	6930	7.26950e-01	6.7639e+00
Fins with Rectangular Notch	34906	74312	8211	2.00193e-01	1.7041e+01

VI. NAMED SECTION AND BOUNDARY CONDITION'S

In this CFD analysis the naming of section is a major thing in fluent the bottom surface of the fins is named as Inlet and the top extruded surface is named as outlet then the left side end of the fin is named as a Boundary-1 and the right side end of the fins are named as a Boundary-2.

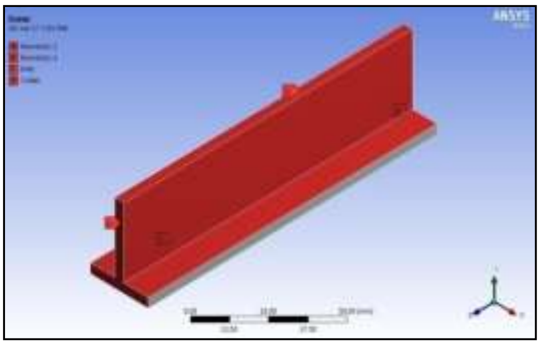

Fig.9: Named Section in Fluent

The above figure will represent the named section given in CFD, after the mesh generated the boundary conditions are defined for CFD domain and the mesh file is save as in the name of .msh format and the mesh file is imported in fluent for analysis. The data for the CFD analysis is given below as follows,

Material – Air

- Density- Bousinqness = 1.1768Kg/m^3
- Specific Heat ,Cp= 1005 J / Kg-k
- Thermal Conductivity , K = 0.0262 W/m-k
- Viscosity , v =1.8249e-05 Kg/m-s
- Thermal Expansion co-efficient , 1/ k = 0.0033

Material – Solid (Aluminium)

- Inlet Velocity of Air is 0.1 m/s
- Inlet Air Temperature 300k

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- Operating condition 1atm

VII. RESULTS IN CFD

A three-dimensional model is developed to investigate flow and heat transfer rate in the automobile fins. A series of numerical calculations have been conducted by FLUENT and the results are presented in order to show the effects of temperature distribution, overall heat transfer coefficient, heat transfer rate and velocity of the heat flow. The results are calculated for 20 Iteration Cycles and the iteration graph are given below,

Graph from Fluent

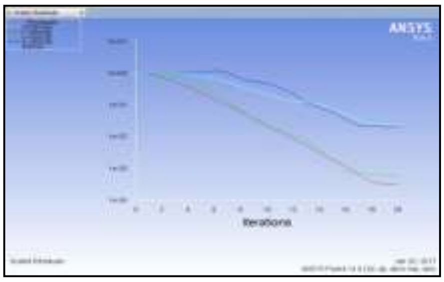

Fig.10: Iteration Graph from Fluent For Normal Fins

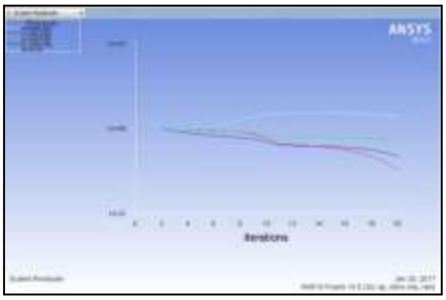

Fig.11: Iteration Graph from Fluent For Fins with Holes

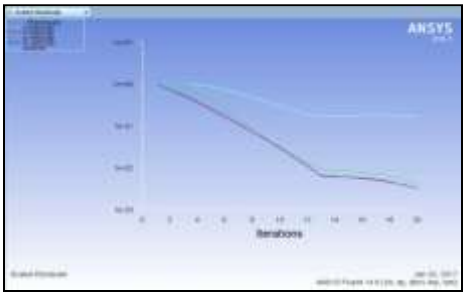

Fig.12: Iteration Graph from Fluent For Fins with V – Shaped Notch

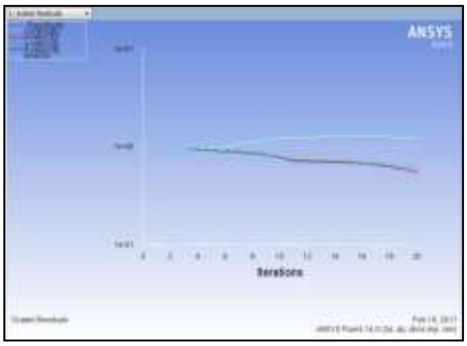

Fig.13: Iteration Graph from Fluent For Fins with Rectangular Shaped Notch

A) TEMPERATURE CONTOUR

After the analysis are done the results are seen in CFD post processing , by choosing the domain the results are seen by means of vectors and contour diagrams the following images shows the temperature contour of various notches and the results are given below.

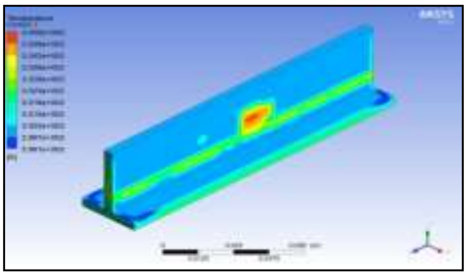

Fig.14: Temperature Changes in Normal Fins

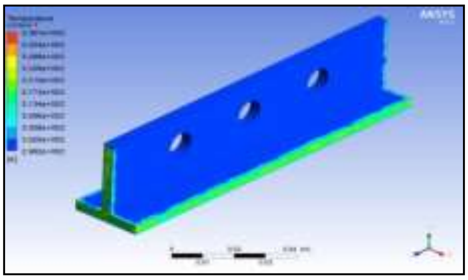

Fig.15: Temperature Changes in Fins with Holes

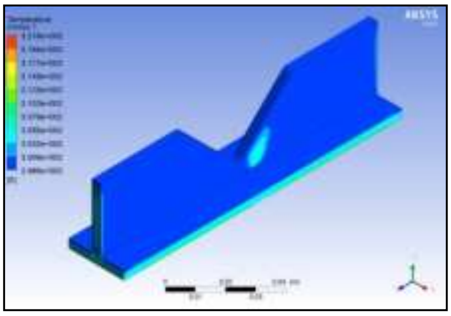

Fig.16: Temperature Changes in Fins with V – Shaped Notch

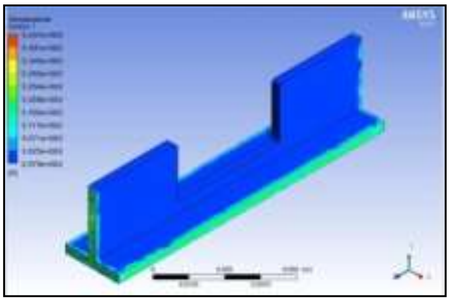

Fig.17: Temperature Changes in Fins with Rectangular Notch

Due to the change in shapes of the fins the temperature distribution is varied in the above figures and it can be determined by using CFD fluent. The following graph will represent the changes in the temperature of the fins under same operating condition.

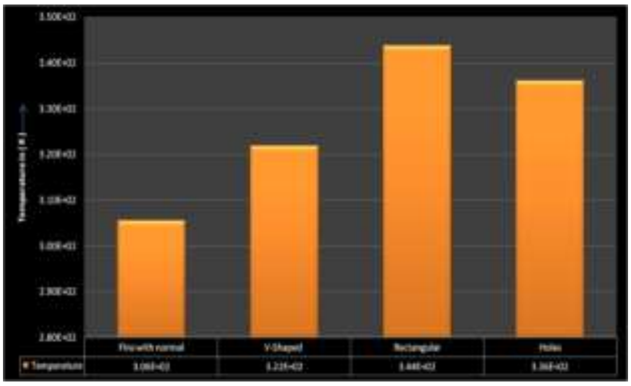

Fig.18: Graph showing Temperature Changes of the Fin

B) VELOCITY CONTOUR

Due to the change in shapes and because of different notches the surface area of the fins are increased and the atmospheric air contact portion is also increased, So the large amount of air is passed through the fins since the heat dissipation rate is increased on each fins, the following images shows the velocity contour of various notches and the results are given below,

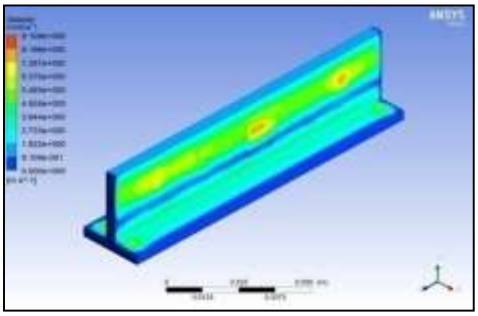

Fig.19: Velocity Changes in Normal Fins

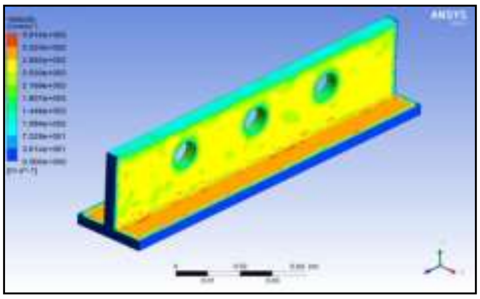

Fig.20: Velocity Changes in Fins with Holes

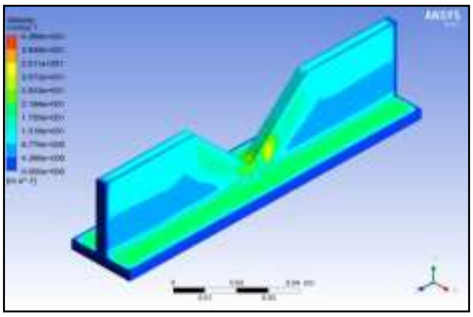

Fig.21: Velocity Changes in Fins with V – Shaped Notch

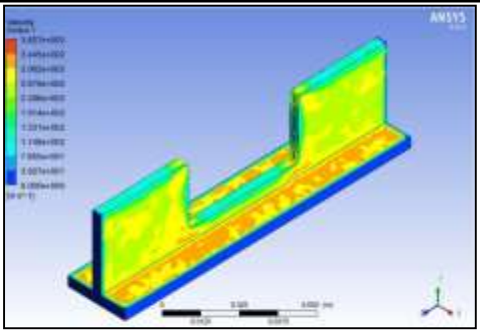

Fig.22: Velocity Changes in Fins with Rectangular Notch

The above figure will shows the velocity changes in all types of fins. From the results of the different fins the graph is drawn to find the best and effective fin with high heat transfer rate and the graph is shown below,

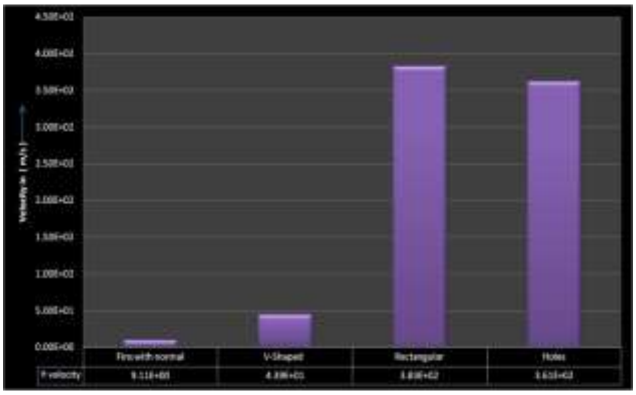

Fig.23: Graph showing Velocity Changes of the Fin

C) HEAT FLUX CONTOUR

Heat flux is the rate of heat energy transfer through a given surface per unit time. Since the surface area of the fins are increased in different notch so the heat transfer rate is also increased, the following images shows the heat flux contour of various notches and the results are given below.

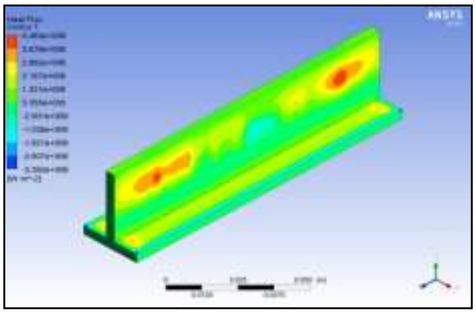

Fig.24: Heat Flux Changes in Normal Fins

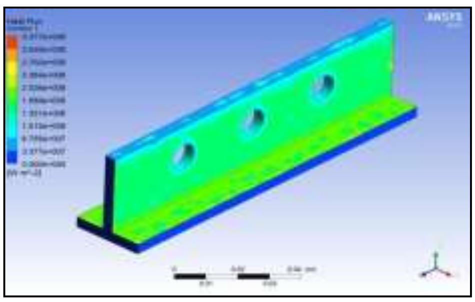

Fig.25: Heat Flux Changes in Fins with Holes

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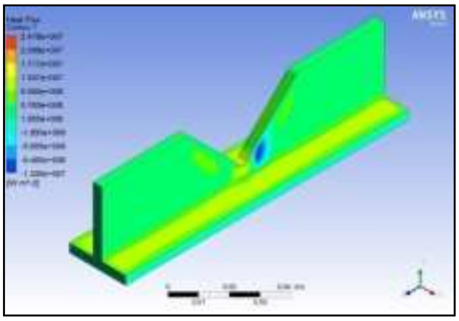

Fig.26: Heat Flux Changes in Fins with V – Shaped Notch

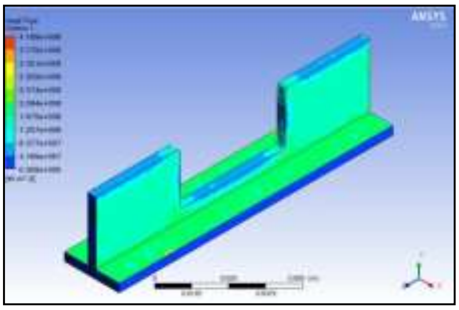

Fig.27: Heat Flux Changes in Fins with Rectangular Notch

The above figure will shows the Heat flux changes in all types of fins. From the results of the different fins the graph is drawn to find the best and effective fin and the graph is shown below,

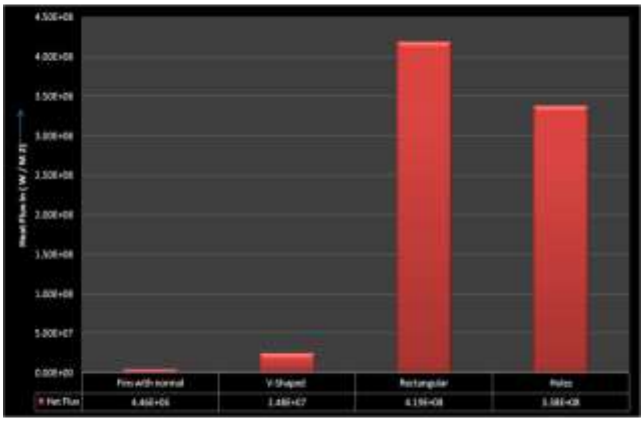

Fig.28: Graph showing Heat Flux Changes of the Fin

From the above analysis which is done in CFD – Fluent, the various analysis such as temperature contour, velocity contour and Heat flux contour are taken and the results are discussed below. Thus the same operating conditions are specified and the change in output values are seen by using CFD – Post processing

3D ANALYSIS RESULT

Table.3: Results from CFD- Fluent

Parameter	Fins with normal	V-Shaped	Holes	Rectangular
Temperature	3.06E+02	3.22E+02	3.36E+02	3.44E+02
velocity	9.11E+00	4.39E+01	3.61E+02	3.83E+02
Het Flux	4.46E+06	2.48E+07	3.38E+08	4.19E+08

The above table will clearly shows the result from CFD – Fluent. From the above results we can easily conclude that rectangular notch is more effective when it compared with other notches. Since the rectangular notch has more heat transfer and temperature distribution than other notches.

VIII. THEORETICAL CALCULATIONS

Let us consider a normal cross section fins of Length , L and Perimeter , P and heat transfer rate , Q and thermal conductivity , K

Gas Temperature, T_∞ = 298 K (Ambient Temperature)

Base Temperature, Tb = 300 K

Thermal Conductivity of the Fins, K = 202.399 W/m-k

Heat transfer Co-efficient, h = 140 W/m^{2}k

Surface area of the a Rectangle

$$= 2 (LxW + LxH + WxH)$$

Surface area of a fin, A1

$$= [2 (130x26) + (130x4) + (26x4)]$$
$$= 8008 \text{ mm}^2$$

Surface area of a fin, A2

$$= [2 (130x4) + (130x4) + (4x4)]$$
$$= 2112 \text{ mm}^2$$

Total Surface area = A1 + A2

$$= 8.008 + 2.112 \text{ m}^2$$
$$= 10.120 \text{ m}^2$$

Total Surface area, A = 10.120 m^2

Perimeter of the Fin = 2 (L+w)

$$= 2 (4+130) + 2 (26+130)$$

Perimeter , P = 0.580 m^2

$$m = (hp / kA)^{0.5}$$

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$m = [(140 \times 0.580) / (202.399 \times 10.120)]^{0.5}$

$\mathbf{m = 0.199}$

Heat Transfer Rate,

Heat Transferred

$Q = [(hpkA)]^{0.5} *(Tb-T\infty) * \tanh(m L)$

$Q = (140 \times 0.580 \times 202.399 \times 10.120)0.5 \times (300 - 298) \times \tanh (0.199 \times 0.130)$

Q = 21.0960 Watts

Heat Transfer Rate, Q = 21.0960 Watts

The Theoretical calculation for the normal fins are calculated and the heat transfer rate is found by using formulas. By using same method the surface area and perimeter are modified and the heat transfer rate is calculated for all types of notches. The below table will clearly shows the heat transfer rate theoretically.

Table.4: Theoretical calculation of the fins with different notches

Shape of the Fins	Surface Area in m^2	Perimeter in m^2	Heat Transfer Rate (Q) in Watts
Fins with Normal shape	10.120	0.580	21.0960
Fins with Holes	10.967	0.6742	24.525
Fins with V – Shape Notches	13.870	0.680	24.710
Fins with Rectangular Notches	13.220	0.730	26.554

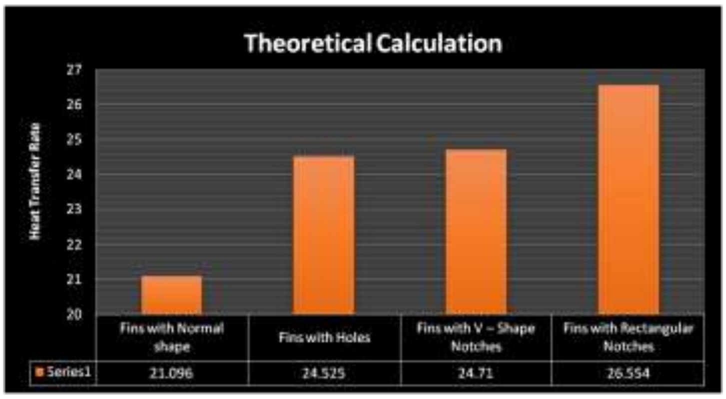

Fig.29: Graph showing theoretical calculations of the Fin with various notches

From the above table and figure we can easily understand the heat transfer rate of fins with different types of notches, from the figure : 29 the rectangular notch has more heat transfer when it is compared with other notches. So we can easily conclude that rectangular notches have more heat dissipation capacity.

IX. CONCLUSION

The fins with various configurations were modeled using CREO 2.0 and analyses are done by using CFD – Fluent in order to find out the heat transfer rate. It is clear that the results from software and theoretically says that the fins with rectangular notch have greater heat transfer rate compared to that of the fins without holes, fins with holes and V shaped fins. Since the heat dissipation rate is more in rectangular notch so we conclude that the rectangular notch fins are most efficiency and best heat transfer notch among all types of notch.

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